Lab Notebook and Report

Lab Philosophy:

Labs differ from lectures in some important ways. Recognizing the following will help you carry out the experiments and report the results more successfully.

While an experiment is often organized around measuring a particular physically quantity (e.g. the acceleration due to gravity, *g*), getting that one final value is *not* the main aim of the experiment in the context of your education. If you get a very accurate value for the measured value, yet your record of the experiment, your report, and your work in general fails to follow scientifically acceptable practices, the experiment is still considered a failure.

After all, in the example mentioned, the value of *g* is well known, what is the point of having you measuring it again? You do it because you are being trained to properly record, analyze and report experimental findings. You are being graded not purely on how close your value is to the accepted value, but whether you could demonstrate clearly how you achieved that value. If you have a lot of sophisticated math and graphs that led to your final value, yet nobody understands what those things mean, then you will not receive a passing grade.

Similarities and differences between a formal lab report and a lab notebook

Both prepare you to one day becoming a scientist or a researcher. Writing a lab report is akin to writing a publishable scientific paper reporting your findings. On the other hand, the notebook is meant to be your real-time record of what you did and observe during the experiment. The notebook is written *during* the experiment while a formal report is usually produced after the experiment is finished.

Lab Notebook:

Buying lab notebook: The lab notebook should be bound so the pages will not come loose, and have duplicate copy pages (which you submit to me after each experiment). I recommend getting one with at least 100 pages to be on the safe side, if you decide to get less pages, you can always buy a second one later. The bookstore should carry some. On Amazon, you can search for the terms “lab notebook carbon copy” for a wide selection. Use the links below for two examples, and cost about $20.
http://www.amazon.com/Notebook-Carbonless-Pages-Spiral-Perforated/dp/0978534425/
http://www.amazon.com/Student-Lab-Notebook-Spiral-duplicate/dp/1930882742/

The notebook is by no means neat and will normally contain crossed out words, sentences, sections or pages. Some people find this hard to accept and choose to either write their initial data on separate sheets for later transfer to the notebook or they enter the data in pencil in the notebook so that it can be erased if necessary. Both procedures are wrong. The data taken is a permanent part of the record of performing an experiment, especially if an error was made that was later corrected. Therefore, all information is entered in the notebook in ink. You want to avoid making an error and not realize it. It is clear that it is very suspicious when a notebook looks particularly clean and neat.

- Should be handwritten in ink (not pencil), except for clearly labeled graphs or printouts from the computer that you may glue to the report.

- If one step does not work, or a data point is found to be invalid, cross it out by a thin line across it, and explain your reasoning below. A modified step could be written afterward.
- A number alone is meaningless, without a description, appropriate units, and an associated estimate of uncertainty. Label each column in data tables and give units.

Your lab notebook must include the following:

Table of content: Leave the first two pages of the notebook for a table of contents (one table of content for the whole notebook).

Title, name and date: Include the experiment title, your name, and the date on which the experiment was performed. When working in groups, include the names of the members in your group. You do not have to use the title suggested by the lab manual if you can think of a more descriptive title.

Purpose: State the main objective of the experiment in your own words in less than five sentences.

Setup: This section should describe how the experiment was setup, what equipment was used. Typically your description should include at least one diagram of the apparatus (see the section on "diagram" below).

Procedure and data: This is the heart of your lab notebook. Honestly write down every step you are doing during (not after) the experiment as well as your observation. This needs to done every time you perform a new step. The procedure and data needs to be complete so that another person can recreate the entire experiment from your descriptions alone. Ideally, before you begin your experiment, you would think about what data you are planning to collect, draw a blank table, and as you perform the experiment, you enter your data into the table. In some cases, like in a one-off measurement, it is okay to record your data right after a particular step as opposed to writing in a separate section, so the "procedure" and "data" sections may not really be two separate sections. Overall, however, it is still advisable to keep as clearly and as separate as possible "what you did" versus "what data you got / observations you made".

- *Procedure*: How did you measure each parameter? How was your data obtained? Was the data obtained from observation? From a photograph? Was the number provided by the professor? You should provide details as to what instrument produced which parameter. In some labs involving computers, the lab manuals may consists of steps on how to set up the computers. In this case, you do not have to repeat and write what buttons you have pushed to set up the computer. Instead your procedure should focus on the physical aspects, such as what quantities you are meaning. For instance, if the button "C" on the computer is used to measure current, instead of writing "push button [C]", you should say what the button is for, and write "the computer was set up to measure current".
- *Data*: Your notebook must contain all the data you obtained in this experiment, including rejected data (crossed out, not erased, with justification noted). You can present it in a table format. If tables are already provided in your handout, you should still copy the table to your notebook and record the data on the notebook. Always include units and use scientific notation when convenient. Keep an eye on

your significant figures, you will lose points if you keep too many significant figures way beyond the precision of the experiment.

Analysis: This section should contain the equations and calculations you used to analyze your results. Please be clear and organized and show your work. *I don't want to see just the final answer. I want the steps you took to arrive to the answer.* In some experiments, there may be several trials of repeated measurements. In this case, the calculations for each trial are almost exactly the same, so there is no need to write the calculations for every trial. Instead you only need to do a sample calculation for one of the trials. You should indicate which trial you are calculating, seeing that the calculations of one trial is correct, I will trust that you know how to do the rest.

Sources of Error: All experiments have some sources of error, in other words, no matter how carefully one designs an experiment there will always be a percentage difference with theoretical predictions. You should list and explain every single source of error carefully. Be sure to list as many sources of error as you can think of, not just the major source. In particular, "carelessness" or "mistakes in calculations" are not acceptable sources of experimental error. Do not write things like "there may be something wrong with the equipment" without addressing what specifically may be the source of error.

*Conclusion***:** Provide a summary of the experiment in less than half a page. The conclusion must be related to the purpose of the lab. Be thoughtful and make careful analysis, and be as quantitative as possible. For example, when you compare your measured value with an accepted value, state explicitly the percentage error by writing something like "the measured value is within 4.7% of the accepted value". When you are testing a particular law, you should write something like "Newton's Second Law is verified to within 3%". Statements such as "the measured value is pretty close to the accepted value", or "Newton's Second Law is correct" are too vague and will not suffice as a conclusion.

Questions: If the lab manual contains questions, answer them in this section.

Other things that will boost your grade:

Diagrams: Almost all experiment should include at least one diagram, for example, when explaining the setup of the experiment. The diagram should have the dimensions and settings of the apparatus. The diagram can be drawn by hand or with a computer. All diagrams should be numbered (e.g. Figure 3).

Graphs: Graphs are often instrumental in the analysis of the experimental results. A graph must have a descriptive title. The title should strive to convey to the reader what the experiment is about and what the graph aims to illustrate. An obvious title like "*P vs V*" is not good enough; instead something like "*The change in pressure of pure oxygen as result of changing volume at constant temperature*" does a better job in describing the graph. It is a good practice to add a subtitle to the graph: a sentence or two to state the main conclusion drawn from the graph, such as "The graph indicates pressure is proportional to the volume." Both axes must be labeled, and the units should be put in parentheses. It is often useful to write short paragraph explaining the graph right below it. Justify the choice of plot. A sentence like "We expect the voltage V to decay exponentially with time so plot logV (voltage) vs. t (time) to obtain a straight line" is all you need. All graphs should be numbered (e.g. Figure 3).

Formal Lab Report:

The formal report is meant to provide experience at communicating the results of an experiment. The intended audience is your colleagues who have not done the experiment and have not read about it. Clear and concise writing is an essential element in a useful report so that reports are limited in length to no more than five pages of typewritten text (font size should be 12 or above) (not including figures and tables). Handwritten reports are not acceptable. Note that Greek symbols and equations may be added by hand, if you keep it neat. Graphs, diagrams, and data tables should be individually labeled (e.g. Figure 1, Table 1); they may be on separate pages, and are not part of the 5-page limit. Cut and paste procedures for tables and figures are acceptable.

Your report must include the following sections:

Title Page:

- Include the experiment title, your name and the date. When working in groups, include the names of the members in your group. You do not have to use the title suggested by the lab manual if you can think of a more descriptive title.
- The title page must also contain succinct, well-written abstract. In general, the abstract briefly states what you did, summarizes the principal results, and mentions the work's significance, if any. Do not exceed 150 words.

Introduction: An overall description of what the experiment is about in your own words and its main objective. Five sentences or less is usually sufficient. Do not copy and paste please.

Theory: Briefly review the theory behind the experiment and include the theory's numerical predications. The measurement results will be compared to the predictions of the theory.

Setup: This section should describe how the experiment was setup, what equipment was used. Typically your description should include at least one diagram of the apparatus (see the section on "diagram" below).

Procedure: This section should describe how the experiment was performed. How did you measure each parameter? How was your data obtained? Was the data obtained from observation? From a photograph? Was the number provided by the professor? You should provide details as to what instrument produced which parameter. In some labs involving computers, the lab manuals may consists of steps on how to set up the computers. In this case, you do not have to repeat and write what buttons you have pushed to set up the computer. Instead your procedure should focus on the physical aspects, such as what quantities you are meaning. For instance, if the button "C" on the computer is used to measure current, instead of writing "push button [C]", you should say what the button is for, and write "the computer was set up to measure current".

Data: This section must contain the relevant data you obtained in the experiment. They should typically be in a table format. You can copy over the tables provided in your handout. Always include units and use scientific notation when convenient. Keep an eye on your significant figures, you will lose points if you keep too many significant figures.

Analysis: This section should contain the equations and calculations you used to analyze your results. Please be clear and organized and show your work*. I don't want to see just the final answer. I want the steps you took to arrive to the answer.* In some experiments, there may be several trials of repeated measurements. In this case, the calculations for each trial are almost exactly the same, so there is no need to write the calculations for every trial. Instead you only need to do a sample calculation for one of the trials. You should indicate which trial you are calculating in your report, seeing that the calculations of one trial is correct, I will trust that you know how to do the rest.

Sources of Error: All experiments have some sources of error, in other words, no matter how carefully one designs an experiment there will always be a percentage difference with theoretical predictions. You should list and explain every single source of error carefully. Be sure to list as many sources of error as you can think of, not just the major source. In particular, "carelessness" or "mistakes in calculations" are not acceptable sources of experimental error. Do not write things like "there may be something wrong with the equipment" without addressing what specifically may be the source of error.

*Conclusion***:** Provide a summary of the experiment. This is the section that will most seriously affect your grade. The conclusion must be related to the purpose of the lab. Be thoughtful and make careful analysis, and be as quantitative as possible. For example, when you compare your measured value with an accepted value, state explicitly the percentage error by writing something like "the measured value is within 4.7% of the accepted value". When you are testing a particular law, you should write something like "Newton's Second Law is verified to within 3%". Statements such as "the measured value is pretty close to the accepted value", or "Newton's Second Law is correct" are too vague and will not suffice as a conclusion.

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